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CATALYTIC POTENTIAL OF MOR HUMUS LAYERS AS AN INDICATOR OF BIOLOGICAL ACTIVITY[1]

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Abstract

Knowledge of the degree of biological activity of holorganic soil layers is essential to foresters for three reasons: It influences the rate of forest growth, the intensity of silvicultural cuttings, and the choice of biodegrading material for amelioration of nursery soils impaired by eradicants. Information on this attribute of humus layers was obtained by manometric determination of their catalytic potentials (Cp). Biologically inert humus layers, associated wih retarded release of nutrients and depressed growth of forest stands yielded catalytic potentials within the range of 4 to 35 mm of mercury. On the other hand, many thick, so-called "raw humus" layers exhibited high biological activities expressed by catalytic potentials from 103 to 139. Such layers were confined to forest stands of high site indexes indicating no deleterious retardation of nutrient cycling.

Additional Index Words: **holorganic layers, raw humus, matted and friable mors, lichen crusts, nutrient cycle, biodegradation of eradicants, site index, Greek-Latin terminology, forest soils.**

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THE ABILITY OF SOILS AND HUMUS to break down hydrogen peroxide (H_2O_2), termed catalytic potential or catalytic capacity, is largely due to the influence of enzymes excreted by microorganisms and roots of plants (Stoklasa, 1922). At one time, the catalytic capacity was said to be an indicator of soil fertility. Later this claim was repudiated because it was found that the ability of soil to decompose H_2O_2 can be due to the presence of ferrous iron and manganese at different states of oxidation. Moreover, humus layers of highly fertile fine-textured soils and those of coarse outwash sands in some cases yielded similar catalytic results. In consequence, catalytic potential has become a "Cinderella" among soil analytical procedures. The introduction of potent eradicants in large-scale production of nursery stock, however, has radically changed the significance of catalytic reactions. As reported by Iyer et al. (1972), Iyer and Wilde (1976), Wilson et al. (1975), Iyer and Oilschlager (1977), and Morby et al. (1978), catalytic potential determinations facilitated detection of adverse influences of manganous fungicides, periodically impeded drainage, and residual eradicants, as well as beneficial effects of detoxifying and biodegrading amendments. The present study indicates that catalytic reactions sharply delineate two groups of forest humus layers of radically different ecological significance: Biologically inert holorganic layers that retard release of nutrients and depress the growth of forest stands, and biologically active holorganic layers with an adequately rapid nutrient cycle. The latter group includes many thick, so-called "raw humus" layers present in forest stands with a very high rate of growth. The biologically inert humus usually requires addition of N fertilizers to correct its high C/N ratio, along with a considerable opening of the canopy by partial cuttings (Wilde, 1958). Stands with biologically active humus require very conservative partial cuttings, and this humus serves as one of the most effective amendments for biodegradation or detoxification and reinoculation of nursery soils impaired in their productivity by biocidic treatments (Mader, 1960; Iyer and Oilschlager, 1977).

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Materials and Methods

The determination of the catalytic potential (Wilde et al., 1972) was improved by the following modification. A sample of soil or humus is taken with 10-ml calibrated scoop. The sample is placed into a 200-ml wide-necked reaction flask with a perforated no. 9 rubber stopper. The stopper has a small tube inserted for attachment of Tygon tubing and an 18-ml container held by a wire (Fig. 1). The container is filled with 15 ml of 6% H_2O_2 (one part of 30% H_2O_2 and four parts of water). The container is carefully introduced into the reaction flask, and the flask is tightly stoppered. The Tygon tubing is attached by means of a leuer connector to an aneroid manometer (an inexpensive 200-mm pressure gauge). The flask is tipped to allow the H_2O_2 to pour onto the sample and is shaken intermittently to bring all of the soil or humus in contact with the liquid. To prevent explosion or escape of free oxygen, the stopper should be held firmly by hand. After exactly 2 min of oxygen evolution, the manometer reading is taken. The results are expressed in millimeters of mercury (Hg). Duplicate determinations, as a rule do not differ more than 5 mm Hg.

Catalytic analyses were supplemented by electrometric determinations of pH values and muffle furnace determinations of the contents of organic matter (Wilde et al., 1972). Average increments were determined either by ocular estimates or on the basis of height over age quotient and yield tables.

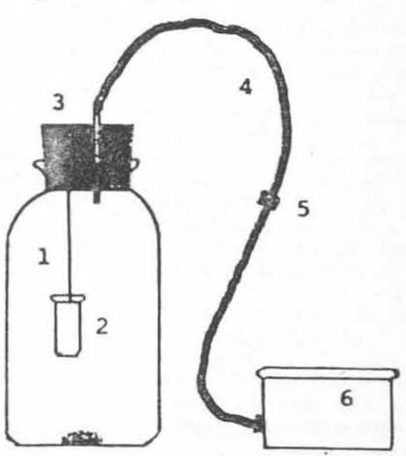

Fig. 1—Equipment for determination of the catalytic potential of humus: *(1)* 200-ml reaction flask, *(2)* 18-ml reagent container, *(3)* no. 9 rubber stopper, *(4)* tygon tubing, *(5)* leuer connector, and *(6)* aneroid manometer.

Table 1—Characteristics of ectorganic humus layers of Wisconsin and the rate of growth of their parent forest stands.

Types of humus layers and forest cover	Thickness of humus layers	Content of organic matter	Reaction	Catalytic potential	Ave. annual increment
	cm	%	pH	mm Hg	m^3/ha
1. Bog mor on silt loam; black spruce (*Picea mariana*)	12	88	4.0	4	0.4
2. Lichen crust mor on dune sand; jack pine (*Pinus banksiana*)	1.3	66	4.5	32	2.0
3. Matted mor on clay podzol; balsam fir (*Abies balsamea*)	10	75	4.2	9	3.5
4. Matted mor on loam podzol; hemlock (*Tsuga canadensis*)	12	68	5.2	28	3.2
5. Matted mor on sandy loam podzol; hemlock	10	63	4.9	103	5.0
6. Friable mor on sandy loam over fragipan; balsam fir	7	62	4.9	130	5.8
7. Fen mor on gley podzolic clay; balsam fir	11	21	5.1	112	5.6
8. Matted mor on podzolized sandy loam; white pine (*Pinus strobus*)	7.5	81	4.3	107	8.5
9. Friable mor on podzolized silt loam; hard maple (*Acer saccharum*)	10	72	5.0	139	4.0

Main features of the representative Wisconsin humus layers analyzed and the associated forest ecosystems are given in the following descriptions, including both the traditional and the Greek-Latin humus terminology (Wilde, 1971).

1) *Bog mor* (Spaghnum uliginor): 12-cm thick, brown, spongy layer of partly decomposed moss and heath plants on Wien silt loam (Mollic Ochraqualfs) of semi-swamp class (Klingelhoets et al., 1968). About 100-year-old stand of black spruce wiht *Ledum-Chamaedaphne* ground cover; 40 to 50 m^3/ha. Vicinity of Parrish, Langlade County.

2) *Lichen crust* (Cladonia crustar): About 1.25-cm layer of dry reindeer moss on Plainfield sand, dune phase (Typic Udipsaments). Sporadic jack pine, 46 years old, with *Cladonia-Hudsonia* ground cover; 90 m^3/ha. Big Flats, Adams County.

3) *Matted mor* (Lentar): 10-cm thick, dark-brown mat on podzolized Ontonagan lacustrine clay (Glossic Eutroboralfs). Volunteer balsam fir with some white and black spruce, about 60 years old, with *Linnaea-Cornus* ground cover; 210 m^3/ha. Vicinity of Amicon Falls, Douglas County.

4) *Matted mor* (Ligno-mycelial lentar): 12-cm thick, dark-brown to red mat with abundant fungal mycelia on morainic, strongly podzolized Karlin fine sandy loam (Entic Haplorthods). Hemlock with some yellow birch (*Betula alleghaniensis*) and balsam fir, about 120 years old, with *Clintonia-Lycopodium-Coptis* ground cover; 380 m^3/ha. Near Atkins Lake, Ashland County.

5) *Matted mor* (Lentar): 10-cm thick, dark-brown to red, tenacious layer on strongly podzolized Pence sandy loam (Typic Haplorthods) over ground moraine. Hemlock and balsam fir, 120 years old with *Taxus-Clintonia-Lycopodium* ground cover; 600 m^3/ha. Highway WW, Menominee County.

6) *Friable mor* (Leptorm): 7-cm thick, dark-brown to black, partly consolidated litter enriched in exoskeletons of arthropods on podzolized, gravelly Pence sandy loam (Typic Haplorthods) of pitted outwash with silica-infiltrated fragipan. Hemlock with some balsam fir and hard maple, 90 years old, with *Clintonia-Mitchella-Cornus* ground cover; 520 m^3/ha. Old Hwy 47, Oneida County.

7) *Fen Mor* (Sapronel): 11-cm thick layer of partly dispersed, black organic matter over a gley-podzolic lacustrine clay of Ontonagon series (Glossic Eutroboralfs). About 50 years old, second-growth balsam fir with *Equisetum-Galium* ground cover; 280 m^3/ha. Madeline Island, Bayfield County.

8) *Matted mor* (Mycelial lentar): 7.5-cm thick, brown, compressed raw humus with a dense network of fungal mycelia on Pence sandy loam derived from pitted outwash enriched in silicated minerals (Typic Haplorthods). A remnant of virgin white pine over 200 years old with heights exceeding 50 m and an estimated volume of well-stocked stands of 1,700 m^3/ha; *Gaultheria-Maianthemum* ground cover. Off Hwy M, Menominee County.

9) *Friable mor* (Vermiolic lentar): 10 cm thick, dark, spongy raw humus with many *Lumbricus terrestris* worms on Kennan podzolized morainic silt loam (Typic glossoboralfs). Hard maple with some basswood (*Tilia americana*) and *Liliaceae* ground cover; about 150 years old. The yield of nearly 600 m^3/ha is one of the highest for hard maple in Wisconsin. Near Porcupine Lake, Florence County.

Results and Discussion

According to the prevalent notion of the foresters, especially those of central Europe, accumulation of organic debris > 5 cm signifies arrested release of nutrients and depressed growth of forest stands (Wittich, 1952). This thesis in many instances, is not borne out in forests of Wisconsin where stands of white pine, hemlock, yellow birch, and even exacting hardwoods, such as hard maple and basswood, often attain the limits of their growth potential on soils with layers of raw organic matter varying in thickness from 7 to as much as 12 cm.

Within well-defined and undisturbed ecosystems, humus layers exhibit remarkable uniformity in their reaction, content of organic matter, and catalytic potential, the variations seldom exceeding 0.2 pH units, 7% loss on ignition, and between 2 and 5 mm Hg. Table 1 incorporates the average results of triplicate analyses of holorganic humus layers located on the same sites and estimates of the average annual increments of their parent forest stands. The outstanding feature of these analyses is the wide difference between the catalytic potentials of biologically active and biologically inert humus layers. The correlation analysis for the relationship between catalytic potential (x) and average annual increment yielded an r of 0.72.

The results in their entirety suggest that the nutritional, silvicultural, and soil-ameliorating value of humus layers is expressed better by their catalytic potentials than by their morphology. Obviously, beneficial effects of superficial humus layers emanate from the microbial conversion of raw organic matter into available nutrients. The low values of the catalytic potential of < 35 mm Hg reflect subdued microbiological activity and a grossly retarded release of nutrients by the true "raw humus" layers consisting predominantly of lignin and dead fungal mycelia. On the other hand, catalytic potential values in the proximity of 100 mm Hg of holorganic layers, regardless of their thickness, reveal an intense microbial activity and release of an adequate supply of nutrients permitting an acceptable rate of growth, often exceeding an average annual increment of 5 m^3/ha. It must be stressed that this average increment refers to naturally established, often over-mature forests with gradually decreasing rates of growth, usually less than one-half the growth rate of managed, even-aged stands not older than 80 years.

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